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Building Structured Spreadsheets

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Robert L. Black

College of Commerce and Business Administration
Bureau of Economic and Business Research
University of Illinois Urbana-Champaign

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FACULTY WORKING PAPER NO. 89-1566

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May 1989

Building Structured Spreadsheets

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Coopers and Lybrand, Washington D.C.

Building Structured Spreadsheets

by

Dan N. Stone* and Robert L. Black**

May, 1989

Janis Carter and Eleanor Jordan provided valuable comments on an earlier draft of this paper.

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Abstract

The increasing use of electronic spreadsheets by accounting professionals has made many time-consuming tasks simple and easy. However, most accounting professionals do not recognize that electronic spreadsheets are computer programs. Computer professionals use structured programming techniques to help prevent programming errors. Accounting professionals can similarly benefit by applying structured programming principles when constructing electronic spreadsheets. In this article, we offer recommendations for incorporating structured programming techniques in the design of electronic spreadsheets. These principles will help accounting professionals prevent electronic spreadsheet errors and reduce the costs of maintaining frequently-used spreadsheets.

1. Introduction

The controller of James A. Cummings, Inc. was entering information in an electronic spreadsheet for a construction bid on a $3 million office complex. Realizing that he hadn't included $254,000 in overhead costs in the bid he moved the cursor to the top of a column, and entered this amount. In doing so, he failed to notice that the $254,000 entry fell outside of the numbers summed to arrive at the bid amount. Ultimately, the overhead cost was omitted from the bid and James A. Cummings, Inc. sued Lotus Development Corp., creator of the Symphony software package used by Cummings (Ditlea, 1987). However, the lawsuit was later dropped (Wall Street Journal, 1986).

The proliferation of personal computers in accounting practice has led to explosive growth in the use of electronic spreadsheets. Spreadsheets can make tedious, time-consuming chores, such as preparing budgets or forecasts, quick and easy. As the Cummings case illustrates however, spreadsheets can also lead to erroneous projections and invalid models when little attention is given to documentation and validation. In an experiment designed to investigate spreadsheet errors, 44% of the spreadsheets created by experienced users contained significant errors (Brown and Gould, 1987).

One important approach to controlling spreadsheet errors is to establish procedures designed to validate spreadsheets (see Simkin, 1987). Such procedures include performing simple tests of formulas, creating control-checks of tables, and using spreadsheet auditing software. In this article, we suggest another approach: techniques for building logically-organized spreadsheets (Berry, 1986; Ronen, Palley and Lucas, 1989). The guidelines we suggest are founded upon well-established practices used in writing computer programs.

These procedures are useful in preventing spreadsheet errors and reducing the cost of maintaining frequently-used spreadsheets.

2. Spreadsheets As Computer Programs

Spreadsheets are rarely constructed by professional computer programmers. However, spreadsheets are computer programs. A computer program is a set of instructions that specify operations to be performed by a computer (Dale and Orshalick, 1983). With electronic spreadsheets, the instructions are often executed immediately after being entered. For example, the command to sum a column of numbers may be executed by the computer immediately and automatically after data is entered.

A variety of practices and tools have evolved among professional programmers to insure that computer programs operate effectively and efficiently. One technique with proven success in improving the quality of computer programs is structured programming, which formalizes the process of writing and documenting computer programs (Yourdon, 1979). The purpose of structured programming techniques is to build programs that are: (1) designed in compact modules, (2) logically organized using hierarchical design principles, and (3) adequately documented. In this article, we suggest ways accountants can use structured programming techniques to improve electronic spreadsheets.

3. Designing Structured Spreadsheets

Know Your Problem. The first step in creating a "structured" spreadsheet is to turn the computer off and think in-depth about the problem to be solved. For simple problems such as routine budgeting, little thought will be required prior

to beginning a spreadsheet. For more complex problems, such as calculating pension contributions for a large company, creating outlines, specifying input and output, and drawing flowcharts are essential to understanding problem relationships. Important questions to be answered early in the problem definition process include:

* Is this an appropriate spreadsheet application?
* What is the purpose of the spreadsheet program?
* What are the critical formulae and calculations?
* What are the important assumptions?
* What is the data needed to solve the problem?
* What calculations will be performed by the spreadsheet?
* What output is desired from the spreadsheet?
* Will the spreadsheet be used by experienced or novice spreadsheet users?
* Will the spreadsheet be used by just the preparer or by other users as well?
* Will the spreadsheet be used only once or repeatedly?

Use Top-Down Design Principles. Structured programming is based upon using a conceptual, hierarchical design that is completed prior to working on the actual computer program (Yourdon, 1979). In this way large, complex problems can be broken down into smaller, less complex ones, until ultimately only many small, solvable problems remain. A top-down approach to building computer spreadsheets begins with a conceptual design and decomposition of the problem to be solved. For example, a spreadsheet to calculate a bid on a large construction project could be decomposed into smaller modules such as overhead costs, direct labor costs, and direct materials costs. Small spreadsheets could then be constructed to develop estimates for each of these components. The overall bid could be determined by linking together the summary totals from the cost components, either within a single large spreadsheet, or across several smaller ones.

Keep It Small. An important implication of a top-down design approach is to keep spreadsheets small. Large spreadsheets greatly increase the likelihood of errors, because errors are harder to locate and correct. For example, failure to add a cost into a bid is more likely to be seen in a small spreadsheet used only to accumulate overhead costs, than in a large, unsegmented spreadsheet. Structured design principles suggest that splitting large spreadsheet problems into smaller subproblems, and creating separate modules for each problem, reduces errors and makes spreadsheets easier to understand and maintain.

Document Your Work. Quality documentation insures that computer programs are understandable by multiple users. Therefore, documentation increases the life and value of spreadsheets by insuring they are usable even if the original developer leaves. Documentation of spreadsheets begins with documenting the problem description. For difficult problems, flowcharts, outlines, and narrative descriptions of the problem should be included with other spreadsheet documentation. Internal spreadsheet documentation should include aids to increase readability and comprehension. For example, spreadsheet cells containing formulas should include annotated labels and descriptions that explain their function. In addition, the use of blank space to highlight logical modules can significantly aid comprehension.

Spreadsheet Organization. One method of turning big problems into smaller problems was just mentioned: dividing the problem into smaller modules organized by problem area. A related method for creating structured spreadsheets is to create subsections that isolate important spreadsheet functions. We recommend that a spreadsheet be organized into at least four sections, each consisting of a block of cells. These sections are: (a) the introduction, (b) an input section, (c) a calculations section, and (d) a report.

Each of these may have further subdivisions (e.g., multiple reports). The block of cells used for each section can be put in the above-described order and arranged from the upper left "home" cell (A1) downward in a staircase arrangement as depicted in Figure 1. If used, table lookups and macros can be isolated in the upper right-hand corner.

Insert Figure 1 about here

The relative size of each section is not meant to be implied by the block sizes in Figure 1. Obviously, the size of spreadsheet modules will be a function of the problem to be solved. The positioning of sections used in this format promotes good flow from one block to another and provides additional cells for expansion. Although the "staircase" arrangement does not efficiently allocate spreadsheet space, it allows columns and rows to be added and deleted in one block without interfering with the format of other blocks. The "staircase" arrangement therefore both creates logical submodules and allows additions and deletions to modules without interfering with other spreadsheet functions.

To illustrate the subsections of a spreadsheet, consider the budgetary problems faced by Klamath University[1] . Although greatly simplified, this problem illustrates the process of constructing structured spreadsheets, and the resulting product. Klamath University is a private, undergraduate college financed by tuition and donations. Budget deficits have plagued the school recently, and the University President is considering a plan to increase tuition and gifts by 10%, and to relax admissions standards, resulting in a 20%

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[1] Klamath University is fictitious.

increase in students. What are the financial implications of such a plan for Klamath? Figures 2 through 5 illustrate a spreadsheet designed to answer this question.

1st Section: Introduction

The introduction section will be the first section seen by a user loading the spreadsheet. Accordingly, the section should be immediately understandable, and should provide an overview of the spreadsheet. This section should include:

(1) Spreadsheet title and file name.
(2) Date created and most recently updated.
(3) Preparer's and reviewer's names.
(4) A succinct statement of the purpose of the spreadsheet.
(5) A table of contents or index to the various sections of the template (i.e., input section, calculations section, etc.).

Other items that may be included in an introductory section, listed in preferred order of presentation are:

(6) instructions for the user as to how the spreadsheet should (and should not) be used.
(7) a statement of programming logic employed in the template.
(8) a statement of general assumptions and limitations embodied in the spreadsheet design.

Figure 2 shows the introduction section of the Klamath University spreadsheet. Items 1 through 5 from the above list appear in Figure 2 as: (1) the spreadsheet title and file name (on line 4), (2) date created and revised (on lines 5-6), (3) the preparer's and reviewer's signatures (lines 8-10), (4) a statement of purpose (lines 12-15) that makes clear the intended uses of the spreadsheet, and (5) a table of contents (lines 17-20).

Insert Figure 2 about here

2nd Section: Inputs

The James A. Cummings construction bid case discussed earlier illustrates how data entry errors can lead to erroneous spreadsheets. A structured approach to constructing spreadsheets facilitates checking the accuracy and validity of input by isolating all input data in one section. The input section is used to enter ALL data used in the spreadsheet. Numbers used in calculations and report sections should originate in the input section. Accordingly, this is the only section of the spreadsheet that should contain user-input numeric values used for computations. In general, no computations appear in the input section. If necessary, the input section should include instructions as to how and where to enter data.

The Klamath University input section (Figure 3) includes information about expected cash receipts (lines 26-32) and disbursements (lines 34-45) for the University. Disbursement information is given for each type of University employee (lines 34-37) and the number of employees required for each student is stated (lines 39-42). In addition, nonpersonnel-related "other" expenses are stated on a per-student basis (line 45). Note that all input data needed for the Klamath University spreadsheet is entered in the input section.

Insert Figure 3 about here

3rd Section: Calculations

The calculations section of the spreadsheet is used for almost all necessary computations. Information for calculations should be brought forward by cell reference to the input section. Therefore, the calculations section should contain computations (e.g. "AA53*AA60"), and cell references (e.g. "S27") to the

input section, but no user-input numeric values. For example, in the Klamath University spreadsheet, rather than entering "12000" as the current number of students, we instead reference the input cell "S27".

Calculations should be in logical, sequential order, with each operation explicitly labeled. Figure 4 illustrates the calculations section of the Klamath University spreadsheet. Panel A of the figure shows the values that result from computations and cell references in the calculations section of the Klamath University spreadsheet, while panel B shows the formulas that produce those values. The Klamath University calculations section computes the cash receipts (lines 49-62) and expenses (lines 64-84) resulting from current operations and the University President's proposed changes. All computations other than subtotals and totals used in the report appear in the calculations section of the Klamath University spreadsheet.

Insert Figure 4 about here

4th Section: Report

For easy problems requiring only simple computations (e.g. preparing an executive's expense account report, or perhaps even the Klamath University budget), the report and calculations sections may be combined. Usually however, separating the calculations from the report results in more readable output.

The report section consists primarily of cell references to the calculations and input sections. The only computations included in the report section are the subtotals and totals for the report. All other references should be to cells in the

calculation section. If additional input data is needed for the report, it should be entered by cell reference to the input section.

Reports should identify the client, report title, and relevant date(s). To facilitate good report design, it is may be useful to prepare a draft by hand on columnar paper. In general, reports should be no more than one page and be similar in style and content to normally-prepared accounting reports. When supporting computations are necessary they can be attached as supporting schedules. As with all accounting reports, appropriate headings should be used, and footnotes, if needed for clarification, should be included.

The Klamath University report (Figure 5) is a simple statement of cash receipts and disbursements. Panel A of Figure 5 illustrates the values that result from computations and cell references in the report section; panel B shows the formulas that produce those values. Dollar amounts for the receipts and disbursements information enter the report section only by cell reference to the calculations and input sections. Totals for receipts, disbursements, and the excess of receipts over disbursements are computed in the report section. All other computations are done in the calculations section. Because the report is a simple commonly-prepared statement, additional explanatory schedules and footnotes are unnecessary.

Insert Figure 5 about here

---

4. Conclusion

Electronic spreadsheets are computer programs. However, when spreadsheets are created by accountants who are not professional

programmers, they often do not include necessary controls commonly used in the development of computer programs. By introducing structured programming techniques into the design of accounting spreadsheets, accountants can prevent unreliable spreadsheets and reduce the costs of spreadsheet maintenance.

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Figure 1
Spreadsheet Modules

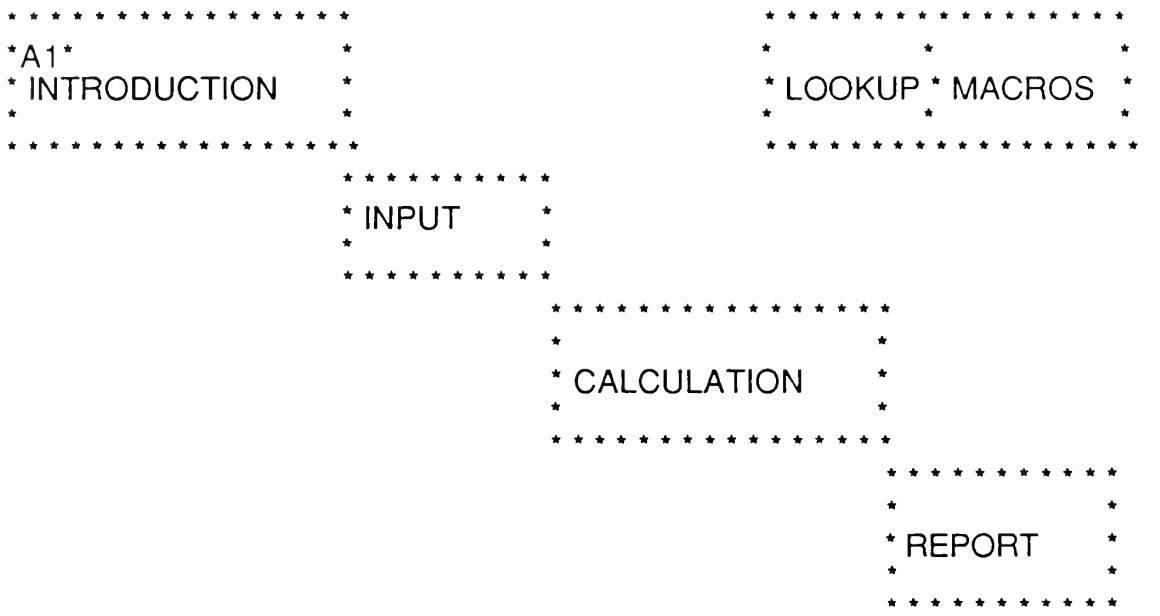

Figure 2
Klamath University Spreadsheet - Introduction Section

```
A1 B C     D       E       F           G                H                I           J        K        L     M N
 2 ********************************************************************************************************************
 3 *Heading:                                                                                                           *
 4 *   Klamath University Financial Projection (Filename: Klamath.wk1)                                                 *
 5 *   Date Prepared: October 12, 1988                                                                                 *
 6 *   Date(s) Revised: May 3, 1989                                                                                    *
 7 *                                                                                                                   *
 8 *   Preparer: _____________________                                                                                 *
 9 *                                                                                                                   *
10 *   Reviewer: _____________________                                                                                 *
11 *                                                                                                                   *
12 *   Purpose: This worksheet projects cash receipts and disbursements for Klamath University for                    *
13 *            fiscal-year 1990, under different financial plans. The first plan is the status quo.                   *
14 *            The second is a proposal by the University President to increase tuition and gifts by 10%              *
15 *            and enrollment by 20%.                                                                                 *
16 *                                                                                                                   *
17 *   Table of Contents (Cell addresses):                                                                             *
18 *            Input            O23 -  T46                                                                          *
19 *            Calculations     W48 - AC84                                                                          *
20 *            Report          AF86 - AL109                                                                         *
21 *                                                                                                                   *
22 ********************************************************************************************************************
```

Figure 3
Klamath University Spreadsheet - Input Section

	O	P	Q	R	S	T	U
22	**********	**********	**********	**********	**********	**********	**********
23	*Input:						*
24	*				Current	President's	*
25	*				Operations	Proposal	*
26	*	Cash receipts information					*
27	*	Enrollment			12000	14400	*
28	*	Tuition (per student/yr)			$4,300	$4,730	*
29	*	Donations/year			$158,000	$173,800	*
30	*						*
31	*	Endowment			$20,000,000	no change	*
32	*	Earnings on endowment			8.00%	no change	*
33	*	----------	----------	----------			*
34	*	Cash disbursements per employee type					*
35	*	Administrative			$52,000	no change	*
36	*	Faculty/library			$35,000	no change	*
37	*	Administrative support			$18,000	no change	*
38	*	----------	----------	----------			*
39	*	Input units required (per student)					*
40	*	Administrative			0.024	no change	*
41	*	Faculty/library			0.032	no change	*
42	*	Administrative support			0.058	no change	*
43	*	----------	----------	----------			*
44	*	Other disbursements (per student)					*
45	*	Miscellaneous			$1,200	no change	*
46	*						*
47	**********	**********	**********	**********	**********	**********	**********

Figure 4 - Panel A
Klamath University Spreadsheet - Calculation Section Values

	V	W	X	Y	Z	AA	AB	AC	AD
48			Calculations:						
49									
50						Current	President's		
51			Cash receipts			Operations	Proposal		
52			Tuition						
53			Tuition per student			$4,300	$4,730		
54			Number of students			12000	14400		
55									
56			Tuition receipts			$51,600,000	$68,112,000		
57									
58			Endowment earnings						
59			Endowment			$20,000,000	$20,000,000		
60			Interest rate			0.08	0.08		
61									
62			Endow. earnings			$1,600,000	$1,600,000		
63									
64			For both plans:						
65			Cash disbursement calculations				# inputs		
66			Disburse. per student			Costs	per student	Cost /student	
67			Administrative			$52,000	0.024	$1,248.00	
68			Faculty/library			$35,000	0.032	$1,120.00	
69			Admin. support			$18,000	0.058	$1,044.00	
70									
71			Cash disbursements per student					$3,412.00	
72									
73							Current	President's	
74			Total disbursements computation				Operations	Proposal	
75			Number of students				12000	14400	
76									
77			Disbursements			Per Student	Total-Current	Total-Proposal	
78							(Stdnts*cost)	(Stdnts*cost)	
79									
80			Administrative			$1,248.00	$14,976,000	$17,971,200	
81			Faculty/library			$1,120.00	$13,440,000	$16,128,000	
82			Admin. support			$1,044.00	$12,528,000	$15,033,600	
83			Other expenses			$1,200.00	$14,400,000	$17,280,000	
84									
85									

Figure 4 - Panel B
Klamath University Spreadsheet - Calculation Section Formulas

```
*  V W       X            Y    Z      AA              AB              AC        AD
*****************************************************************************
48 *Calculations:                                                              *
49 *   ---------------------------------------------                            *
50 *                                 Current      President's                  *
51 *   Cash receipts               Operations      Proposal                     *
52 *     Tuition                                                                *
53 *       Tuition per student           S28            T28                     *
54 *       Number of students            S27            T27                     *
55 *                                                                            *
56 *        Tuition receipts       AA53*AA54      AB53*AB54                     *
57 *                                                                            *
58 *     Endowment earnings                                                     *
59 *       Endowment                     S31            S31                     *
60 *       Interest rate                 S32            S32                     *
61 *                                                                            *
62 *        Endow. earnings        AA59*AA60      AB59*AB60                     *
63 *   ---------------------------------------------                            *
64 *   For both plans:                                                          *
65 *    Cash disbursement calculations              # inputs                    *
66 *     Disburse. per student          Costs     per student Cost /student*
67 *        Administrative              S35            S40       AA67*AB67 *
68 *        Faculty/library             S36            S41       AA68*AB68 *
69 *        Admin. support              S37            S42       AA69*AB69 *
70 *                                                                          *
71 *      Cash disbursements per student                    SUM(AC67..AC69)*
72 *                                                                          *
73 *                                              Current   President's*
74 *   Total disbursements computation          Operations     Proposal*
75 *      Number of students                        S27            T27 *
76 *                                                                          *
77 *      Disbursements          Per Student Total-Current Total-Proposal*
78 *                                        (Stdnts*cost)  (Stdnts*cost)*
79 *                                                                          *
80 *        Administrative            AC67     AB75*AA80       AC75*AA80 *
81 *        Faculty/library           AC68     AB75*AA81       AC75*AA81 *
82 *        Admin. support            AC69     AB75*AA82       AC75*AA82 *
83 *        Other expenses             S45     AB75*AA83       AC75*AA83 *
84 *                                                                          *
85 *****************************************************************************
```

Figure 5 - Panel A
Klamath University Spreadsheet - Report Section Values

*	AF	AG	AH	AI	AJ	AK	AL	AM
85	*Report:							*
86	*	Klamath University						*
87	*	Pro Forma Statement of Cash Receipts and Disbursements						*
88	*	For the fiscal year September 1, 1989 to August 31, 1990						*
89	*							*
90	*				Current	President's		*
91	*	Cash receipts			Operations	Proposal		*
92	*		Tuition		$51,600,000	$68,112,000		*
93	*		Donations		$158,000	$173,800		*
94	*		Endowment earnings		$1,600,000	$1,600,000		*
95	*							*
96	*		Total cash receipts		$53,358,000	$69,885,800		*
97	*							*
98	*	Cash disbursements						*
99	*		Administrative staff		$14,976,000	$17,971,200		*
100	*		Faculty/library staff		$13,440,000	$16,128,000		*
101	*		Administrative support		$12,528,000	$15,033,600		*
102	*		Other disbursements		$14,400,000	$17,280,000		*
103	*							*
104	*		Total cash disbursements		$55,344,000	$66,412,800		*
105	*							*
106	*	Excess (deficiency) -						*
107	*		receipts over					*
108	*		disbursements		($1,986,000)	$3,473,000		*

Figure 5 - Panel B
Klamath University Spreadsheet - Report Section Formulas

```
*     AF     AG        AH        AI                  AJ              AK          AL   AM
*************************************************************************************
 86 *Report:                                                                        *
 87 *    Klamath University                                                         *
 88 *    Pro Forma Statement of Cash Receipts and Disbursements                     *
 89 *    For the fiscal year September 1, 1989 to August 31, 1990                   *
 90 *                                                                               *
 91 *                                              Current    President's           *
 92 *    Cash receipts                           Operations     Proposal            *
 93 *       Tuition                                 AA56          AB56              *
 94 *       Donations                               S29            T29              *
 95 *       Endowment earnings                      AA62          AB62              *
 96 *                                                                               *
 97 *       Total cash receipts              SUM(AJ93..AJ95) SUM(AK93..AK95)       *
 98 *                                                                               *
 99 *    Cash disbursements                                                         *
100 *       Administrative staff                    AB80          AC80              *
101 *       Faculty/library staff                   AB81          AC81              *
102 *       Administrative support                  AB82          AC82              *
103 *       Other disbursements                     AB83          AC83              *
104 *                                                                               *
105 *       Total cash disbursements SUM(AJ100..AJ103)  SUM(AK100..AK103)           *
106 *                                                                               *
107 *    Excess (deficiency) -                                                      *
108 *       receipts over                                                           *
109 *         disbursements                      AJ97-AJ105     AK97-AK105         *
110 *************************************************************************************
```